THE WATER RESOURCES COMPONENT OF THE ECOLOGICAL FOOTPRINT OF A FEDERAL RESEARCH LABORATORY IN ATHENS, GEORGIA

Stephen R. Kraemer, Ph.D.

AUTHOR: Hydrologist, US Environmental Protection Agency, 960 College Station Road, Athens, GA 30605-2700

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Abstract. The water resources component of the ecological footprint (WEF) was calculated for a federal research laboratory in Athens, Georgia for fiscal years 2002, 2003, 2004. The WEF is the land area required to supply the water resources that the laboratory consumes and the land needed to assimilate the wastewater that the laboratory produces in a given year and given prevailing technology. The laboratory WEF was calculated assuming water balance for two conceptualizations: direct capture of rainfall, and source watershed capture of streamflow. The resulting water footprints were highly sensitive to rainfall, and less sensitive to consumption. The WEF for FY2002 significantly exceeded the size of the laboratory property due to the extended drought conditions in Georgia. The EF tool is a useful visual graphic for tracking the effectiveness of the laboratory Environmental Management System (EMS) and documenting progress toward sustainable use of water resources.

INTRODUCTION

Environmental Management Systems (EMS) emerged in the early 1990s to provide organizations with a proactive, systematic approach for managing the potential environmental consequences of their operations. In April 2000, President Clinton signed Executive Order 13148, “Greening the Government through Leadership in Environmental Management” that established a five-year EMS implementation goal for all Federal Facilities.

The ecological footprint is a resource management tool that measures how much land and water a human population requires to support the resources they consume, and absorb the wastes they generate, taking into account prevailing technology (redefiningprogress.org, footprintnetwork.org), (Wackernagel, Rees, 1996). See Figure 1.

The ecological footprint has been reviewed as a metric of sustainability for various economies --- household, city, region, country, global (Commentary, Ecological Economics, 2000), (Marshall and Toffel, 2005). The ecological footprint has been applied to the Los Alamos National Laboratory (Maltin and Starke, 2002). Many of their calculations were based on the estimates of Chambers et al. (2002).

In this paper, I apply the concept of the ecological footprint as a simple metric of resource use and as an integrating metric of a laboratory Environmental Management System (EMS). Specifically, I assess the water resources component of the ecological footprint (WEF) of the Ecosystems Research Division (ERD), US Environmental Protection Agency, Athens, Georgia, for Fiscal Years 2002, 2003, 2004 (a fiscal year runs from 01 October to 30 September).

The water footprint is investigated using the principle of water balance and given the water consumption records of the laboratory. My step-wise approach begins with the assumption of perfect rain water capture, and progresses to an assessment of source water capture within the watershed.

The resulting direct capture water footprints are within the size of the ERD campus property, perhaps indicating sustainable resource use. However, the source watershed footprints are much larger that the ERD campus in size, particularly during dry weather conditions.

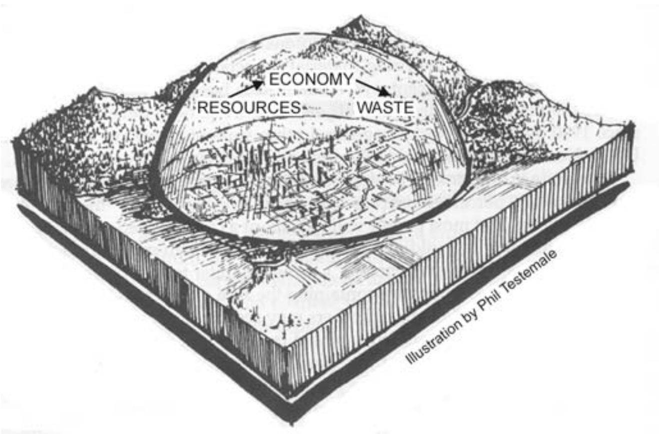

Figure 1. The ecological footprint concept illustrated as a domed economy, after Wackernagel, Rees (1996, Fig. 1.2).

APPROACH

I calculated the water resources footprint of the ERD campus using a step-wise approach, starting with simple idealizations then adding complexity. The analysis was constrained by publicly available data. The analysis was based on the principle of water balance (input - output = change storage).

The ERD campus covers 14.7 acres, including 5.24 acres of roads, parking lots, and buildings which can be classified as impervious surface. The rest of the property contains turf grass, plant beds, and trees.

Water use at the ERD campus supplies drinking water, restrooms, wet chemistry labs, HVAC, and landscape irrigation. Water use per capita is shown in Table 1.

Treated water is provided by Athens Clarke County (ACC) water utility via a water main. The ACC drinking water treatment plants have intakes on local rivers and reservoirs. The North Oconee River intake has a source watershed area of 176,086 acres. The Middle Oconee River intake has a source watershed area of 248,263 acres, and the Bear Creek reservoir intake has a source watershed area of 6,910 acres.

The first conceptualization in the water footprint analysis

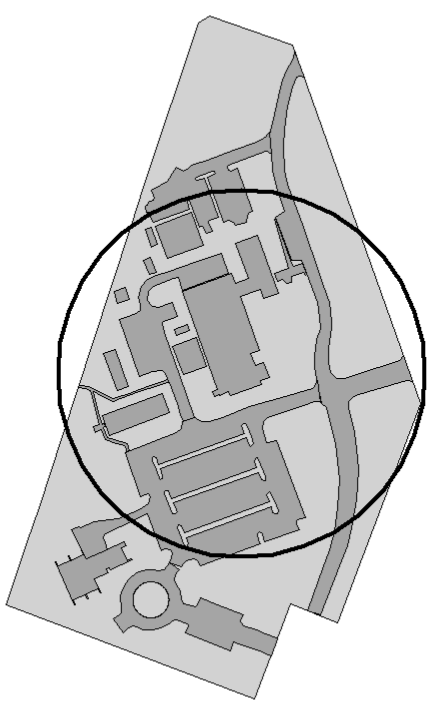

Figure 2 Facility map showing impervious surfaces (darker shaded areas) and equivalent impervious footprint (5.24 acres circle).

Table 1. WATER USE	FY02	FY03	FY04
People	201	200	194
Use (gallon/person/day)	68.7	52.4	51.0

assumed perfect or direct water capture, meaning that all the water needed to supply annual ERD campus consumption, C [dimensions L^3/T], is directly captured from rainfall, r [L/T]. The area of the hypothetical direct capture catchment, A_{dc}, [L^2], is

$$A_{dc} = C / r \tag{1}$$

Direct capture water, separated and stored in rain barrels and cisterns, for example, would be of sufficient quality to be used for irrigation, toilets, HVAC, but treated water supply is needed for drinking water, washing, and human contact.

The second conceptualization in the water footprint analysis recognized that treated water supplied via pipeline to the ERD campus comes from the source watersheds of the ACC water treatment facilities. Not all of the precipitation that falls on the land catchment as rain becomes stream flow. I will show the accounting in Table 2. There are losses due to evapotranspiration. Some of the water goes into soil and aquifer storage. Some of the water goes into surface water storage behind dams. I performed streamflow analysis using the hourly discharge record at Middle Oconee River near Athens (USGS gage 02217500, 398 sq. miles, nwis.waterdata.usgs.gov). The Middle Oconee River watershed has a long term record and I considered this catchment representative for the area. The monthly precipitation record was collected at the Athens Ben Epps airport (www.ncdc.noaa.gov/oa/ncdc.html). I used the baseflow separation software PART (Rutledge, 1998) to characterize streamflow (sf), baseflow (bf), and runoff (ro), normalized to watershed area, [L/T], for FY02-FY04

$$q_{sf} = q_{bf} + q_{ro} \tag{2}$$

Not all of the streamflow is available for extraction for drinking water purposes. Typically, a minimum 7Q10 flow is required in the river for wastewater assimilation. The 7Q10 is defined as the average flow over 7 consecutive days with an average recurrence of once in 10 years, and normalized by drainage area, q_{7Q10} [L/T]. The USGS reports the 7Q10 for Middle Oconee River is 45 cubic feet per second (cfs). More recent understanding of stream ecology recognizes that additional flow may be necessary to support healthy aquatic ecosystems. I will assume that 30% of average annual streamflow be reserved for habitat, and normalized by drainage

Table 2. WATER BUDGET	FY02	FY03	FY04
C, consumption (ft^3)	673,650	510,850	482,500
r, rain (in)	35.30	55.33	39.57
q_{sf}, mean streamflow (in)	7.23	25.85	15.19
q_{bf}, mean baseflow (in)	4.89	15.42	10.93
q_{ro}, mean runoff (in)	2.34	10.43	4.26
q_{7Q10}, minimum streamflow 7Q10 (in)	1.56	1.56	1.56
q_{30}, minimum streamflow 30% avg (in)	5.37	5.37	5.37
q_w, available streamflow less waste assimilation (in)	5.67	24.29	13.63
q_h, available streamflow less habitat (in)	1.86	20.48	9.82

area, q_{30} [L/T]. The 30% average streamflow at Middle Oconee River based on 1929-2001 data was found to be 155 cfs, which is greater than the 7Q10. Therefore, the available streamflow for drinking water extraction less flow for waste assimilation (q_w) and habitat (q_h), normalized by drainage area [L/T], were calculated as

$$q_w = q_{sf} - q_{7Q10}$$
$$q_h = q_{sf} - q_{30} \tag{3}$$

The area of the hypothetical source watershed supporting water consumption is therefore

$$A_{sw} = C / q_h \tag{4}$$

RESULTS

The ecological footprints of the ERD campus for water resources (WEF) defining the equivalent land area needed to supply water were calculated for two conceptual models: (1) direct capture areas; and (2) source watershed areas. The ecological footprint water budget data are shown in Table 2, including water consumption, rainfall rates, and available streamflow, for FY02-04. The resulting calculations for water footprints using equations (1) and (4) are shown in Figure 3. The footprint areas (acres) are drawn as proportional circles, and ERD campus impervious and pervious surfaces areas are shown for scale.

The area of the hypothetical source watershed supporting water consumption may be normalized to average available flow in the Middle Oconee (516 cfs, 1929-2001) or $q_h = 12.23$ in. The resulting normalized water footprints based on the source watershed concept for the ERD campus for FY02-04 are shown in Figure 4.

DISCUSSION

I present an ecological footprint assessment for water resources of the ERD campus for FY02-FY04 assuming first, direct capture of rainfall, and second, watershed capture of streamflow (Figure 3). The footprints are snapshots of the equivalent land area expressed as circles needed to support water consumption. The footprint sizes are influenced by consumption and the available water supplied by rain and streamflow. The footprints can be normalized by average streamflow, as shown in Figure 4, to reveal the influence of consumption alone.

The rainfall in FY02 and FY04 were below average and resulted in larger source watershed footprints in those years, even though consumption was decreasing. I believe the anomalously large FY02 source watershed footprint (Figure 3) reflects the fact that the preceding years were in drought conditions in Georgia, and rain infiltrating the ground satisfied a soil and aquifer storage deficit, first, and return flow to the stream, second.

The elementary water balance footprint analysis presented can be improved. A more accurate method for estimating the volume of rainfall falling within the source watersheds could be developed using rainfall radar and accounting for spatial heterogeneity of events. A watershed specific estimate of source water could be performed based on the percentage of drinking water being supplied to the ERD campus from the three drinking water plants (North Oconee, Middle Oconee, Bear Creek). For example, during the summer of 2002, most ACC drinking water was supplied by Bear Creek watershed in order to protect the 7Q10 minimum flow requirements in North and Middle Oconee Rivers (Shearer, 2002). However, long term observations of stream flow in the North Oconee and Bear Creek watersheds are not available.

The ERD water footprint as presented does not explicitly include the river miles needed to assimilate the wastewater discharges from ACC utilities, although the footprint does account for minimum flows for wastewater assimilation.

An ERD modeling study of waste assimilation in the North Oconee River using the WASP model is being discussed (www.epa.gov/athens/wwqtsc/).

The ERD water footprint does not account for the impact of quick response high velocity water leaving our property based on the amount of impervious surface. The cumulative impact of storm water in the river mobilizes sediment and degrades aquatic habitat downstream. Perhaps a sediment or geomorphology modeling approach could add this additional impact to the water footprint.

The complete ecological footprint of the ERD campus could be calculated for energy use and materials use, and compared to the source watershed footprint. The EF might be considered a metric for prioritizing actions within the Environmental Management System (EMS).

Discussions of sustainability might lead to the goal to manage water consumption and wastewater generation so as to keep the ERD campus source watershed footprint less than or equal to the property area of 14.7 acres. We met that goal in FY03 and FY04, but not in FY02, based on the analysis presented. There are a number of EMS activities that could reduce our water footprint, including installation of rain barrels to capture rooftop runoff for use in irrigation, planting of drought tolerant native vegetation in the landscaping to reduce irrigation, installation of waterless urinals and low flow toilets, building of rain gardens to treat the first flush runoff from parking lots and storm water retention basins to hold back the rest, and replacement of asphalt with pervious pavement in low use parking lots, to name a few.

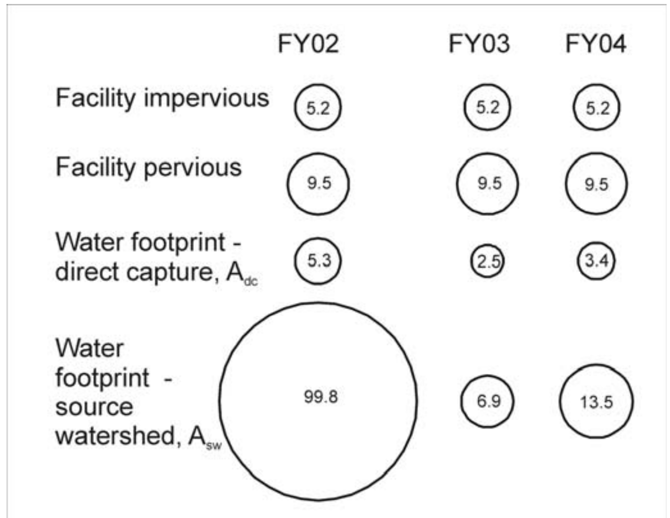

Figure 3. ERD campus water footprints for FY02-04, based on observed available streamflow, shown in relative size (acres).

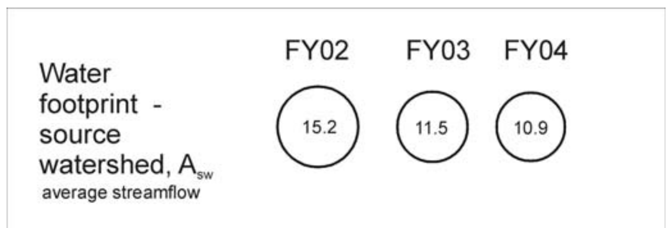

Figure 4. ERD campus water footprints for FY02-04 normalized to average available streamflow, shown in relative size (acres)

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